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TITLE: Temporal Progression of Visual Injury from Blast Exposure"

PRINCIPAL INVESTIGATOR: Brittany Coats, PhD

CONTRACTING ORGANIZATION: University of Utah
Salt Lake City, UT 84112

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14. ABSTRACT

The purpose of this grant is to investigate the temporal progression of eye injury from blast exposure and identify early predictors of visual dysfunction. We propose to accomplish this by first identifying the probability of military personnel developing visual system injury after blast exposure, and determining the time point after blast exposure that visual system injury becomes identifiable. In parallel to the clinical studies, we propose to systematically evaluate the time course of visual system injury from blast exposure using our existing rat model for blast traumatic brain injury. From the studies performed in the previous year, we have found that low-level blast exposure (~225 kPa) in rats appears to result in a general decrease in visual acuity without any signs of stress or pain in the animals.

15. SUBJECT TERMS
Biomechanics, ocular trauma, blast, rats, visual acuity

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON USAMRMC
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
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INTRODUCTION

Ocular trauma during military conflicts has steadily increased from 0.5% in the civil war to 13% in present day. This increase is likely associated with the advancement of weaponry and the increased use of explosive devices. The majority of eye injuries from an explosion can be classified as either open globe or closed globe. Open globe injury is often readily identifiable and typically undergoes urgent surgical repair. However, closed globe injury may not be detected immediately and can result in a series of sequelae that lead to visual dysfunction months after the blast. The progression of closed globe eye injury and visual degradation following blast exposure has not been well characterized. Furthermore, it is unknown if there are early indicators that denote an increased risk for developing visual dysfunction following blast exposure. Therefore, the objectives of this proposal are to investigate the temporal progression of eye injury from blast exposure and identify early predictors of visual dysfunction. We propose to accomplish these objectives by first identifying the probability of military personnel developing visual system injury after blast exposure, and determining the time point after blast exposure that visual system injury becomes identifiable. Next, we propose to systematically evaluate the time course of visual system injury from blast exposure using our existing rat model for blast traumatic brain injury. From these experimental studies we can identify early predictors of visual dysfunction. Finally, we will evaluate these early predictors in a clinic setting to verify their usefulness in real-world scenarios. By understanding the temporal and chemical progression of eye injury from blast exposure, we can establish early identifiers of visual system injury. This will enhance our diagnostic capabilities and lead to the development of time-dependent treatment strategies to mitigate the loss of vision in military personnel.

KEYWORDS: blast, vision loss, biomarkers, pressure, ocular trauma, animal model, clinical study

"

OVERALL PROJECT SUMMARY

Aim 1: Investigate the progression of visual system injury in service members exposed to a blast.

Current Objectives
- Complete a retrospective analysis of the military personnel with visual system injury attributed to blast exposure but not immediately identifiable at the time of the blast. (SOW 1)
- Use the data to identify the probability of eventual visual system injury from blast exposure with and without an associated traumatic brain injury. (SOW 2)
- Statistically determine the time after the blast exposure that visual dysfunction is identifiable. (SOW 3)
- Identify local cases of military personnel with exposure to blast injury and no identifiable signs or symptoms of visual injury (SOW 4)

Key Methodology
University of Utah health records were searched for the following ICD9 codes: E993, E921, E923, E803, E837, E993.4, E890.0, E923.9. These ICD9 codes involve injuries from multiple types of explosions. The target date range was from 2005 to present. Inclusion criteria for this study are (1) No obvious sign of open globe trauma (e.g, facial burns, shrapnel to the eye, etc.) (2) Eye examination following blast exposure. Our control group consists of people involved in other traumatic injuries that would not affect the visual system (e.g., accidental or inflicted trauma to the extremities or torso without an associated head impact).

Medical records will be evaluated for information that may provide insight into the severity of the blast. Any history associated with the blast exposure will be investigated for signs of stand-off distance, height of the explosive, and the type of the explosive. In addition, injuries related to the initial blast exposure will be identified and given an assessment score based on the Abbreviated Injury Scale (AIS) which is an anatomical scoring system for classifying the severity of the injury. An increased injury severity score will be assumed to indicate an increased severity of blast exposure. To maximize efficiency with data collection, we have designed a database within REDCap at the University of Utah. REDCap is a secure, web-based application for building and managing online surveys and databases. This database also allows us to share data with all the IRB approved investigators on the grant. The data entry form created for the database is provided in **Appendix A**.

All statistical analyses will be performed using SAS statistical software (JMP 10.0, Cary,NC). Descriptive and univariate analyses will first be performed to identify the occurrence of delayed visualsystem injury after blast exposure. Of the cases with delayed visual system injury, the time between the blast exposure and diagnosis will be collected. Significant differences with age, gender, the presence of absence of traumatic brain injury, and blast severity will be evaluated. Statistical significance will be set

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at a p-value of < 0.5. Logistic regression will also be used to determine the probability for developing visual system injury following blast exposure given age, gender, blast severity, and the presence/absence of traumatic brain injury. In addition, a survival analysis will be performed using Cox's proportional hazards regression model to determine the time post blast exposure that visual system injury is most likely to be identified. Multiple regression analysis will be used to determine the effect of participant age, gender and blast severity on the survival analysis.

Results

   The retrospective review at the University of Utah resulted in 535 unique medical records. **Table 1** provides demographics for the cases. The majority of these (n=431) did not have a record of an eye exam and have been excluded from the study. Another subset of cases (n=75) were eliminated from the study due to open globe trauma. These include corneal abrasions, corneal lacerations, corneal burns, and foreign body to the eye. We have elected to keep one case of corneal abrasion because it resolved and there was a follow-up exam monitoring vision. The remaining 29 cases are currently being evaluated for details regarding each of the events to determine whether they meet the remaining criteria of the study or will be excluded. Data collection is ongoing, so no statistics have been performed to date.
"

Gender		
	Male	(81.5%) 436
	Female	(18.5%) 99
Age		
	Mean	33.6±17.5 years
	Min	3 months
	Max	88 years
Race		
	American Indian/Alaska Native	0.7% (4)
	African American	0.6% (3)
	Hispanic or Latino	9.5% (51)
	Native Hawaiian/Pacific Islander	0.9% (5)
	Caucasian	62.4% (344)
	Unknown	24.9% (133)
	Other	0.4% (2)
Common Causes		
	Fireworks	15.7% (84)
	Propane-related explosion	11.4% (61)
	Smoking while on oxygen	3.9% (21)
	Cooking incidents	3.6% (19)
	Gun-related incidents	3.0% (16)
	Tire explosion	2.8% (15)

Table 1. Demographics of civilians treated for injuries related to an explosion."

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Progress and Accomplishments
   The retrospective review of the University of Utah records is nearly
complete, but resulted in minimal viable records. A similar review will be
performed at the VA hospital in Salt Lake City. IRB and HARPO approval for
this review has been obtained. The PI met with the polytrauma group at the
VA to inquire about their medical records regarding blast victims. The group
maintains a large (~2000) database of veterans exposed to a blast. All
members in the database get eye exams. They have agreed to allow us
access to their database after we have obtained clearance through the VA.
This clearance process was started June 2014. It should be complete by Oct.
3, 2014. After this approval, we will access the VASLC database and
continue the review. As soon as the retrospective review of the VA records is
complete, statistical analysis will commence.
   IRB applications for the prospective portion of this study (SOW 4) is
nearly complete and will be submitted in October 2014.

**Aim 2: Investigate the progression of visual system injury following
blast exposure in an animal model and identify early indicators of
visual dysfunction.**

Current Objectives
   - Manufacture new blast device with enhanced mach stem overpressure
     capabilities. (SOW 1)
   - Establish randomized testing protocol for 12 experimental groups: 4
     severities of blast exposure (140kPa, 260kPa, 450kPa, Control) each
     with 3 survival periods (1 day, 1 wk, 4 wks). (SOW 2)
   - Complete experimental studies investigating temporal changes of
     visual system injury from blast exposure. (SOW 3)
   - Complete Animal OCT and behavior studies to test visual function on
     all animals prior to blast exposure and at 1 day, 1 wk or 4 wks post
     injury (SOW 4)
   - Complete histology for ocular injury from blast exposure. (SOW 5)

Key Methodology
   To verify that our experimental design will result in a low mortality rate,
the low blast level was evaluated first before proceeding to the high blast
level. Briefly, adult Long Evans rats were administered carprofen one day
before the blast for pain management. A baseline of vision functionality was
established before the blast using the custom optokinetic tracking device we
developed in Year 1 (**Figure 1A**). For increased accuracy, each animal is
tested three times on each testing day and an average acuity is used for the
final measurement.
   On the day of the blast, the animal is anesthetized using inhaled
isoflurane followed by an injection of ketamine and dexmetomedine
administered IP. The anesthetized animal is placed in the custom rat holder
also designed in Year 1 (**Figure 1B**) to provide a side-on blast exposure

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while preventing injury to the animal torso. After blast exposure, the animal is removed from the device, allowed to recover from the anesthesia, and then returned to the animal facility. While animals do not show signs of pain following the blast exposure, carprofen is administered the next day as a precaution. The vision metrics (vision behavior, OCT) are then repeated the day after the blast and every subsequent week following the blast until sacrifice. At sacrifice, the eyes and brain are harvested for later analysis. As detailed in the Year 1 annual report, the length of the survival period was increased to 8 weeks and the number of blast levels investigated was decreased to three.
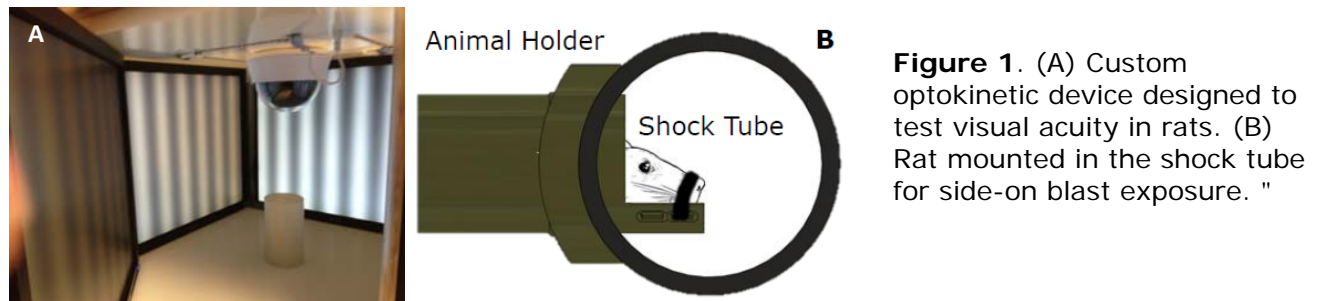

Figure 1. (A) Custom optokinetic device designed to test visual acuity in rats. (B) Rat mounted in the shock tube for side-on blast exposure. "

In addition to monitoring retinal thickness over time, we have added an evaluation of the corneal damage following blast exposure. Corneal damage will be assessed by measuring corneal thickness via OCT, with flourescein staining, and with indirect examination by a resident ophthalmologist. For OCT image analysis, we have developed two MATLAB image processing programs to evaluate the thickness of the retina and the cornea. The retina image processing program automatically measures the thickness of the retina and RPE layers as shown in **Figure 2**. Thickness of both the retina and RPE was measured for every pixel column and then averaged across the image. The average for each image was then averaged with other images in the same retina region. The regions are defined in relation to the optic nerve: superior medial/distal (SM/SD), inferior medial/distal (IM/ID), nasal medial/distal (NM/ND), and temporal medial/distal (TM/TD).
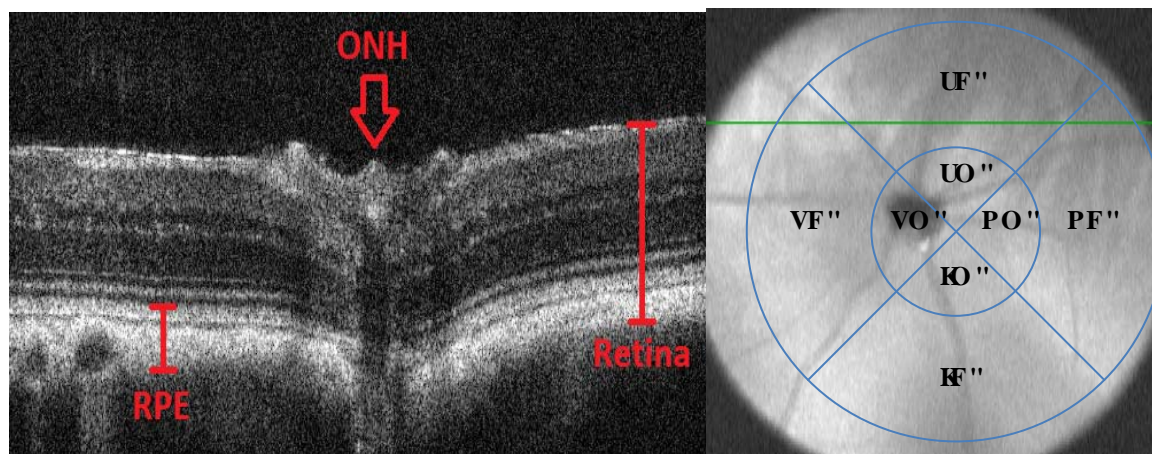

Figure 2. (A) Optical coherence tomography (OCT) is used to monitor changes in the retinal thickness. (B) The thickness of the RPE and retina are averaged across regions defined by a radial pattern around the optic nerve of the eye.

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The corneal thickness program is semi-automated. Each frame of an OCT region is presented and a user selects a non-noisy region of the cornea to analyze (**Figure 3**). The thickness of cornea was determined across the entire cornea by calculating the distance of every pixel point on the top of the cornea image to the corresponding point on the bottom edge. Pixel distances are converted to millimeters. An average thickness was determined for each frame. Subsequent frames from the same eye are analyzed and all the frames for a single cornea are averaged.
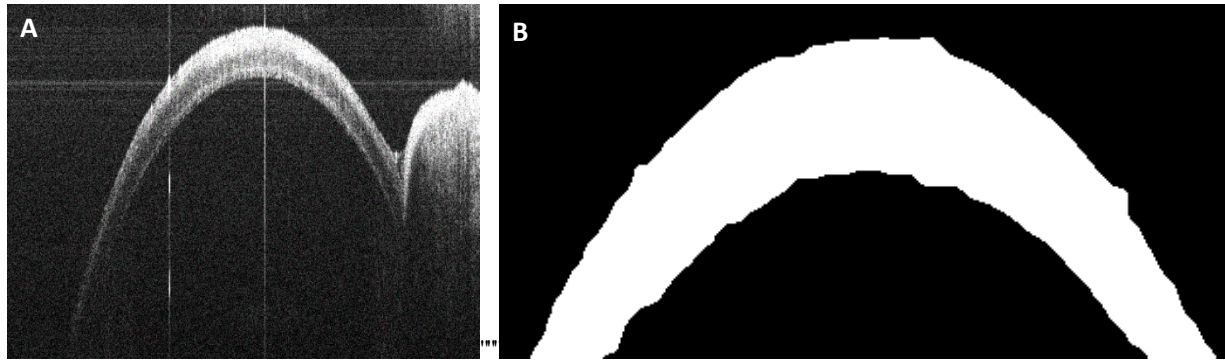

Figure 3. (A) Optical coherence tomography (OCT) is used to monitor changes in the corneal thickness. (B) A custom image processing script removes any skew from the original OCT image and then creates a binary image of the cornea. Thickness is averaged across the entire cornea for each frame.

Results

To date, 54 animals have been evaluated at low blast pressures. Two of these animals were used to determine the effect of the blast on intraocular pressure (IOP). We have had no mortalities to date and are currently making preparations to shift to the higher pressures. In the animals tested to date, there was a significant initial drop in visual acuity from rats exposed to a blast compared to controls. Over the period of 8 weeks, the acuity did not continue to get worse, but it also did not recover to baseline levels (**Figure 4**). In fact, the visual acuity from control animals appeared to improve slightly, likely due to increased familiarity of the animals with the optokinetic device and less distraction by their surroundings during testing.

Retinal thickness was normalized to baseline values and compared with controls for 8 weeks. In several regions, there appeared to be a slight thickening of the retina at week 2 (**Figure 5**). This thickening resolved, however, by week 8. Additional data needs to be analyzed to validate this trend with statistical significance. The program was unsuccessful in extracting thickness in lower quality images. These images are currently being evaluated by hand to estimate retinal thickness.

Evaluation of corneal injury was added later in the study and only a limited number of animals have been evaluated to date. In this limited data set, there does not appear to be any change in corneal thickness (**Figure 6**) within 1 day after injury, however, the single animal analyzed 1 week post injury had a substantial thickening compared to baseline. Interestingly,

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fluorescein staining shows some indication of corneal damage (**Figure 7**). Eye exams by an ophthalmologist will be added to future studies to better determine injury to the cornea.
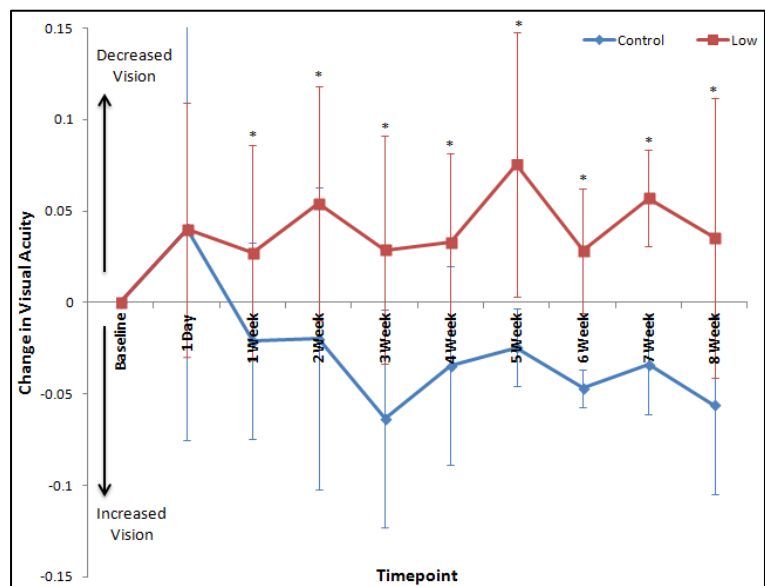

Figure 4. Behavior test results from 26 control and 26 low-level blast animals. *indicates significant differences between control and animals experiencing a low-level blast pressure (p<0.05).

Figure 5. Representative graph of the retinal thickness normalized by baseline values. Several regions appeared to have a slight thickening after two weeks that resolved around 7 weeks. Additional data needs to be collected to validate observational trends with statistical significance.

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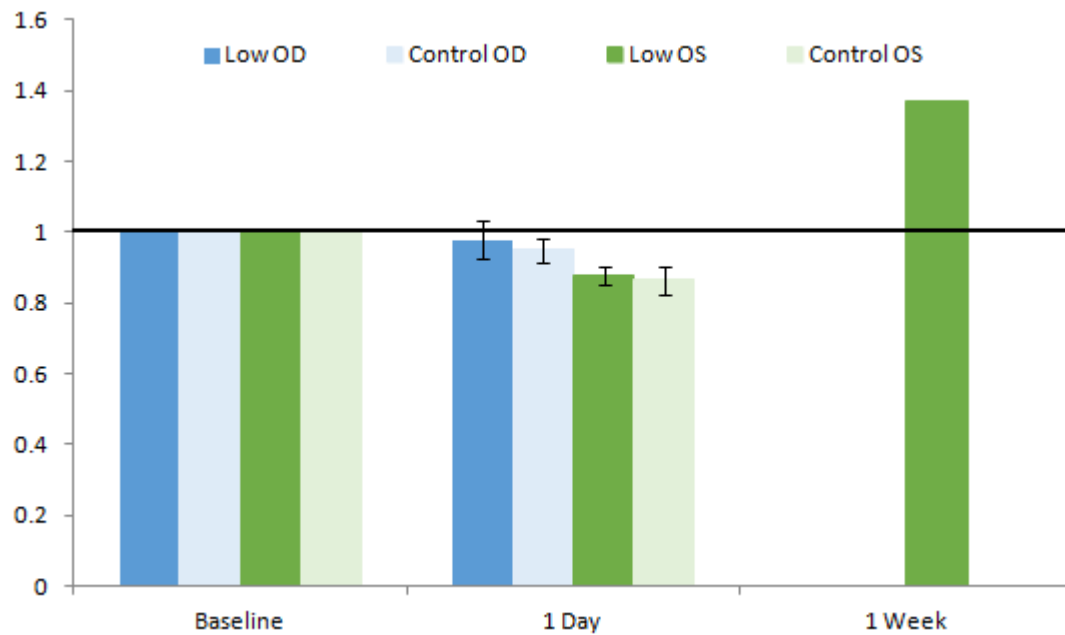
Figure 6. Early analysis of corneal thickness following blast exposure. This analysis was added mid-study, so only a limited number of animals have been complete (n=3 each 1 Day group; n=1 for the 1 week group). Additional animals (n=15) are currently being analyzed. All of the high blast pressure animals will be evaluated for corneal injury.
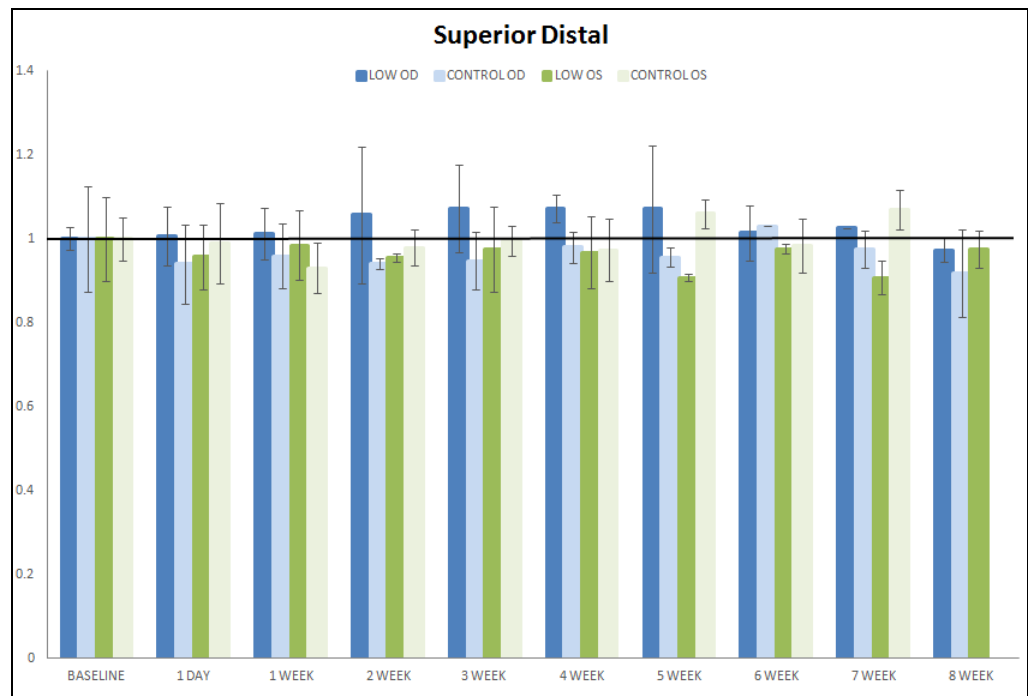

Figure 7. Representative graph of the retinal thickness normalized by baseline values. Several regions appeared to have a slight thickening after two weeks that resolved around 7 weeks. Additional data needs to be collected to validate observational trends with statistical significance.
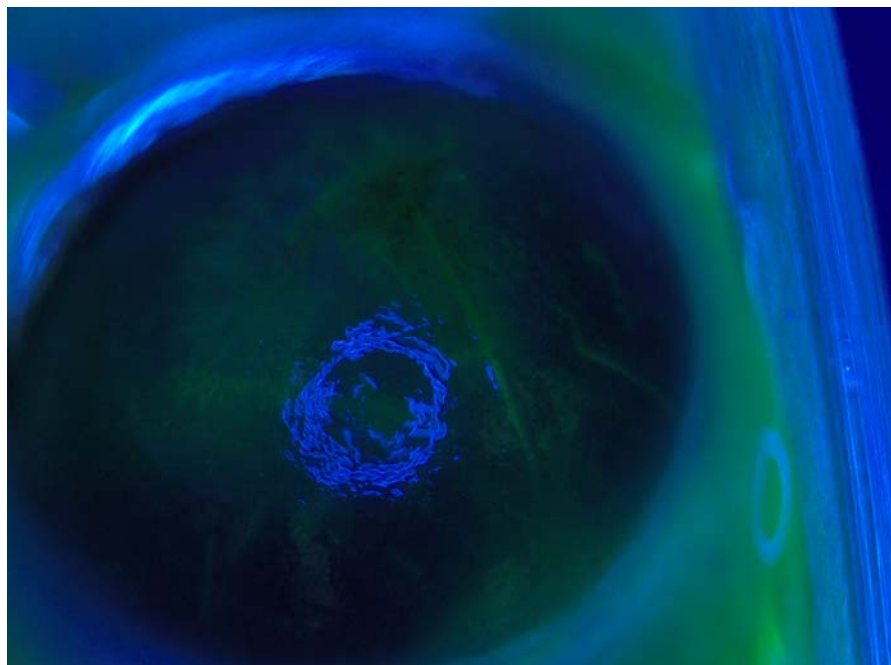
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Progress and Accomplishments

At the end of the previous funding year, we were modifying the device to decrease the decibel levels reported by the University's Environmental Health and Safety. The modifications included the design and construction of a silencer and dump tank. The final design is shown in **Figure 8**. A steel barrel lined with 2″ of acoustic foam was selected as the dump tank. It surrounds a rubber barrel lined with foam composite. The steel barrel is allowed to recoil on a cart, absorbing energy of the pressure wave. Recoil is limited to small motions by placing 2″x4″ blocks behind the cart wheels. The silencer was designed so that it did not introduce changes to the blast profile. This was verified during preliminary tests which show the overpressure of the reflected wave utilizing the new silencer/dump tank design is still less <20% of the magnitude of the primary shock wave and is after the negative phase.

Figure 8. (Left) Inner silencer assembly completed during Q4 of Year 1. (Right) Final silencer assembly with the outer steel drum completed Q1 of Year 2. The device successful reduced sound below Environmental Health and Safety limits, but still creates a Friedlander wave profile with minimal reflection."

In preparation for the high blast level studies, all pressure regulating components have been upgraded to handle 280 psi. The upgrade included replacements to the solenoid air valve, pressure tubing, tube fittings, air supply hose, and secondary pressure regulator. After the upgrade was completed, it was discovered that high driver pressures caused premature release of pressure because the membranes were pulling out from the grip of the driver and driven sections. Changing membrane materials did not solve the problem. Therefore, custom clamping plates were designed to better grip the membrane (**Figure 9A**). The new plates are in the process of being tested. Thus far, they have been able to withstand driver pressures up to 135 psi. The driver pressure is typically 3 times larger than the pressure experienced by the animal. Therefore, the goal is to achieve 195 psi.

There is some concern that the animals might be receiving complex loading schemes involving both blast pressure and head acceleration. To verify this is not happening, 2 changes to the system were recently made. First, linear accelerometers were placed on the mount to measure vibration. Even without the additional weight of the animal, the maximum displacement of the mount is < 0.5 mm. Second, the end section of the shock tube was replaced with a clear PVC tube (**Figure 9B**). In the future high blast pressure studies, a high-speed video camera will be used to record head motion during each blast test.
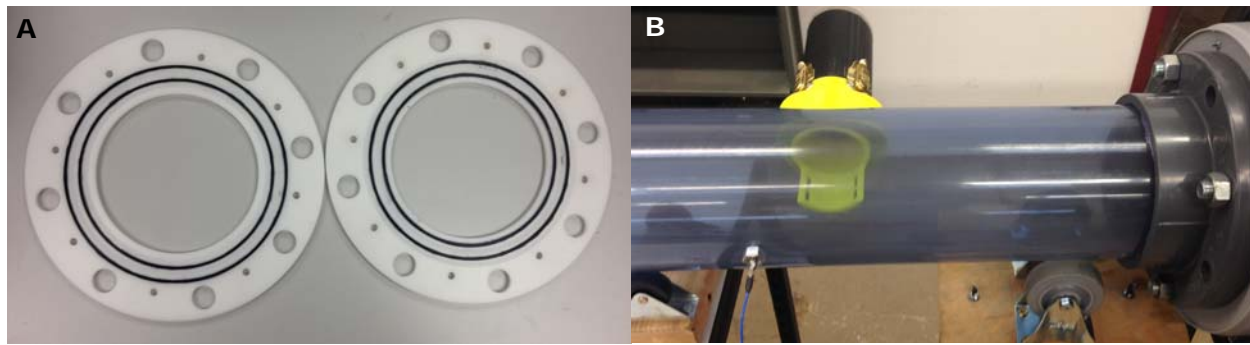
Figure 9. (A) Clamping plates designed to better grip the membranes during high pressure. (B) A clear PVC pipe now surrounds the blast impact area to monitor head motion during the blast. "

Aim 3: Identify changes in vitreous protein expression that correlate with visual system injury
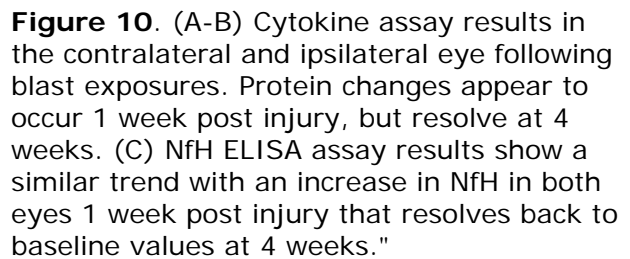
Current Objectives
- Collect vitreous samples following every animal experiment in Aim 2. (SOW 1)
- Assay samples for NfH, VEGF, IL-10, MCP-1, and MIP-3 (SOW 2)

Key Methodology

The vitreous from half of the animals in each group were evaluated for biomarkers of ocular trauma. VEGF and other cytokines are measured using a commercially available antibody array (RayBio Rat Cytokine Antibody Array G, RayBiotech, Norcross, GA). Signal intensities are be evaluated using an ELISA plate reader at an excitation frequency of 532 nm. Positive and negative controls in the array allow comparison between different array analyses. All samples are tested in duplicate on a single plate and the average intensity is recorded for statistical analysis. To evaluate changes in neurofilament-heavy chain (NfH) following blast injury, a method similar to that presented by Petzold et al. is used will be used. All samples are tested in duplicate on a single plate and the average intensity is recorded for statistical analysis.

Results

Currently, eyes from 24 animals have been analyzed. The remaining eyes are being stored in a -80°C freezer as assays are more economically performed in batches of 24. **Figure 10** shows average results from the cytokine and NfH analyses. Statistical comparison is impractical at this point, but looking solely at trends it appears that Ciliary Neurotrophic Factor (CNTF) is decreased 1 week after the blast and then returns to baseline levels. VEGF appears to be increased at 1 week post blast and then returns to baseline levels. These changes occur in the contralateral eye instead of the ipsilateral eye. A similar pattern is found for both eyes with NfH. NfH is increased 1 week post injury and resolves at 4 weeks. Accompanying

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pathology for these eyes will help elucidate the injury patterns in both eyes of the animal.

A"

B

C"

Figure 10. (A-B) Cytokine assay results in the contralateral and ipsilateral eye following blast exposures. Protein changes appear to occur 1 week post injury, but resolve at 4 weeks. (C) NfH ELISA assay results show a similar trend with an increase in NfH in both eyes 1 week post injury that resolves back to baseline values at 4 weeks."

<u>Progress and Accomplishments</u>

We have purchased equipment and developed all the methodologies necessary to analyze the vitreous samples we have been collecting. The equipment includes an orbital shaker, micro-centrifuge, microarray scanner, hot plate, micro-titrate plates, buffers, and the necessary chemicals to run the tests. This includes the purchase of positive and negative control proteins for the ELISA. The control proteins are used to create standard curves to calibrate protein concentrations. Preliminary testing was performed on donor eyes to validate the biomarker assays methods (**Figure 11**). An image processing algorithm was written to analyze the data from the assays. The micropipette used in these tests was sent out for calibration that resulted in some delays with the biomarker testing, but we should be on track to complete the studies in a timely manner. Eyes will continue to be collected and analyzed in batches of 24.
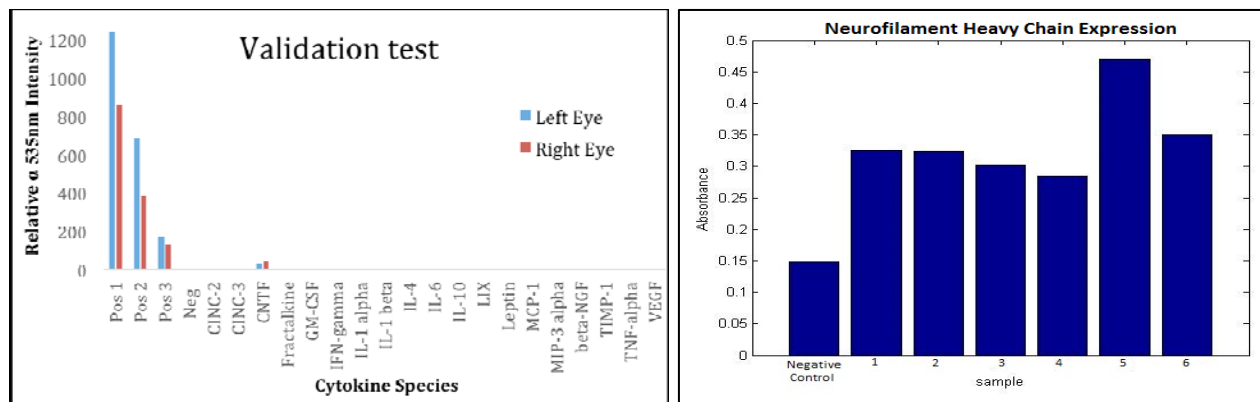
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Figure 11. Validation of cytokine (A) and NfH (B) assays with donor rat eyes from non-trauma related studies. Positive decreasing values in (A) validate the cytokine test. NfH correctly identified in control animals. Injury will increase NfH absorbance.

KEY RESEARCH ACCOMPLISHMENTS:

- Identified immediate decrease in vision following a low-level blast exposure that remains steady until 8 weeks post injury. This was significantly different than control animals which actually improved with time.
- Potentially identified corneal damage from blast pressure only. This finding was unexpected and will be explored in more detail with the high blast studies.

CONCLUSION: The successful completion of the studies proposed in this 4 year project will form the basis for understanding the temporal and chemical progression of visual system injury following blast exposure. In the first year, all the infrastructure and product development was completed to successfully achieve the stated goals of the study. In Year 2, all the clinical and experimental work is underway. Several modifications to the blast device will enhance the future high pressure studies. Data from the animal studies has resulted in some interesting findings regarding visual acuity and corneal injury. These findings will be pursued further in Year 3. Once completed, the results from these studies will expand our understanding of the time-dependent response of the visual system to blast, and help identify potential avenues to mitigate vision loss from blast exposure.

PUBLICATIONS, ABSTRACTS, AND PRESENTATIONS

Abstract & Presentation
Shedd DF and Coats B. Temporary visual dysfunction following low-level blast exposure. 7th World Congress of Biomechanics. Boston, MA July 2014

Book Chapter
Asked to contribute a chapter on military related ocular trauma. This chapter is currently in progress. An official citation will be created in the next annual report.

"

INVENTIONS, PATENTS AND LICENSES:

Nothing to report.

REPORTABLE OUTCOMES:

- Silencer and dump tank developed for 12″ diameter shock tube. Results in minimal change to the resulting pressure profile and results in a 15% reduction in decibel level.
- Designed a clamping system to pressurize shock tubes to high pressures and reduce early membrane failure.
- Developed semi-automated image processing tools for analyzing the thickness of the retina and cornea from OCT data.
- Developed automated image processing tools for analyzing cytokine biomarkers and NfH protein assays.

OTHER ACHIEVEMENTS:

The work from this project has resulted in collaboration with Dr. Barbara Wirostko, an ophthalmologist with a SBIR Phase I grant from the same funding body. Dr. Wirostko is developing biofilms that can be placed in the eye for drug delivery. Given the recent potential corneal injury findings, we are developing plans to use the animal model as a platform to evaluate the drug treatment. We have also discovered that our mechanical engineering and design expertise and tools are useful to enhance the design process for her biofilms. We will be integrating the equipment, tools and methods we have developed in this proposal into Phase 2 of her SBIR.

REFERENCES:

Petzold et al. A specific ELISA for measuring neurofilament heavy chain phosphoforms. *Journal of Immunological Methods.* 278, 179-190 (2003).

APPENDICES:

Appendix A: Data Collection Form on REDCap
Appendix B: World Congress of Biomechanics Abstract
Appendix C: World Congress of Biomechanics Poster
Appendix D: Brittany Coats (PI) CV
Appendix E: Quad Chart

"

Initial Pass Data

Record ID _____

MRN _____

Gender
☐ Male
☐ Female
☐ Unknown

Age at Presentation _____

Height _____
(In inches)

Weight _____
(In pounds)

BMI _____

Race/Ethnicity
☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Hispanic or Latino
☐ Native Hawaiian or Other Pacific Islander
☐ White
☐ Unknown
☐ Other

Other Race _____

History of Present Illness (HPI)

Date of Presentation _____

Date of Explosion (if different than admission date) _____

Burns Present
☐ Yes
☐ No

Description of Burns _____

Glasgow Coma Score _____

HPI Description _____

Head Injury Diagnosis
☐ TBI Present
☐ TBI Absent
☐ No Diagnosis of TBI Recorded

Description of Head Injury Diagnosis _____

Initial Eye Exam

Fluorescein Administered
☐ Yes
☐ No

Result of Fluorescein Test _____

Visual Acuity - Right Eye (OD)

☐ 20/15
☐ 20/20
☐ 20/25
☐ 20/30
☐ 20/40
☐ 20/50
☐ 20/70
☐ 20/80
☐ 20/100
☐ 20/200
☐ 20/400
☐ Count fingers
☐ Light perception
☐ No light perception

Visual Acuity - Left Eye (OS)

☐ 20/15
☐ 20/20
☐ 20/25
☐ 20/30
☐ 20/40
☐ 20/50
☐ 20/70
☐ 20/80
☐ 20/100
☐ 20/200
☐ 20/400
☐ Count fingers
☐ Light perception
☐ No light perception

Visual Acuity - Both Eyes (OU)

☐ 20/15
☐ 20/20
☐ 20/25
☐ 20/30
☐ 20/40
☐ 20/50
☐ 20/70
☐ 20/80
☐ 20/100
☐ 20/200
☐ 20/400
☐ Count fingers
☐ Light perception
☐ No light perception

Pupillary Defect - OD

☐ Yes
☐ No (PERRLA)

Description of Defect

_____

Pupillary Defect - OS

☐ Yes
☐ No (PERRLA)

Description of Defect

_____

Extraocular Motility

☐ EOMI
☐ OD deficit
☐ OS deficit
☐ OU deficit
☐ Other

Other extraocular motility findings not listed above

_____

Visual Field Defect- OD

☐ Yes
☐ No

Description of Defect

_____

Visual Field Defect - OS

☐ Yes
☐ No

Description of Defect

_____

Periorbital Edema Present - OD

☐ Yes
☐ No

Periorbital Edema Present - OS

☐ Yes
☐ No

Conjunctiva Damage - OD

☐ Yes
☐ No

Conjunctiva Damage - OS

☐ Yes
☐ No

Initial Ophthalmic Findings - Additional pertinent
findings not discussed elsewhere

_____

Follow-Up Information

Follow-up at Moran

☐ Yes
☐ No
☐ Unknown

Exclude from study?

☐ Yes
☐ No

Reason for Exclusion

_____

Need PowerChart Access (chart unavailable in Epic)

☐ Yes
☐ No

REDCap

Follow-Up

Visual Acuity - Right Eye (OD)

☐ 20/15
☐ 20/20
☐ 20/25
☐ 20/30
☐ 20/40
☐ 20/50
☐ 20/70
☐ 20/80
☐ 20/100
☐ 20/200
☐ 20/400
☐ Count fingers
☐ Light perception
☐ No light perception

Visual Acuity - Left Eye (OS)

☐ 20/15
☐ 20/20
☐ 20/25
☐ 20/30
☐ 20/40
☐ 20/50
☐ 20/70
☐ 20/80
☐ 20/100
☐ 20/200
☐ 20/400
☐ Count fingers
☐ Light perception
☐ No light perception

Pupillary Defect - OD

☐ Yes
☐ No (PERRLA)

Description of Defect

_____

Pupillary Defect - OS

☐ Yes
☐ No (PERRLA)

Description of Defect

_____

Intraocular Pressure - OD

_____

Intraocular Pressure - OS

_____

Visual Field Defect - OD
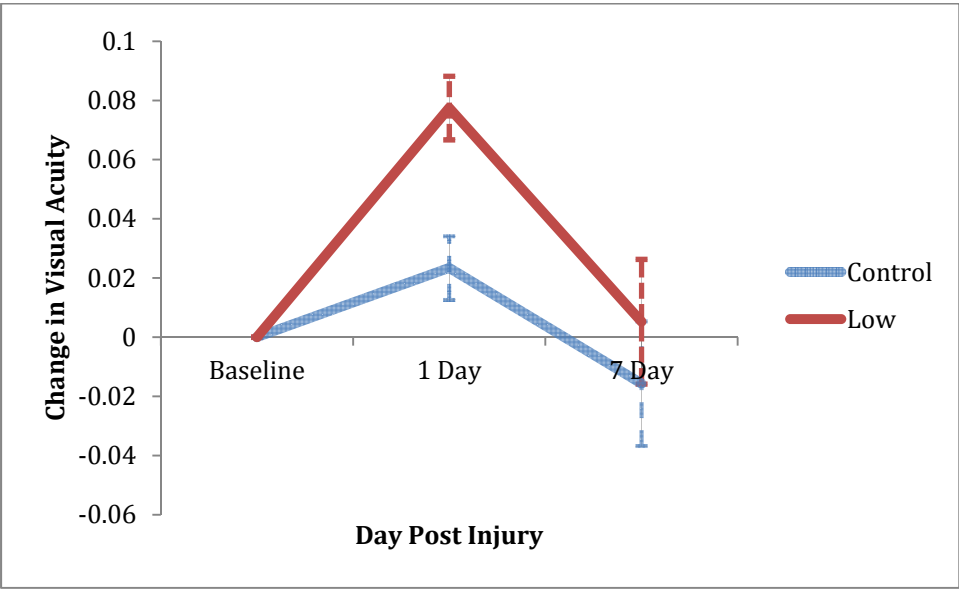
☐ Yes
☐ No

Description of Defect

_____

Visual Field Defect - OS

☐ Yes
☐ No

Description of Defect

_____

REDCap

Title: Temporary Visual Dysfunction following Low Level Blast Exposure

Blast exposure is a leading cause of eye injury for the US Army. Open globe ocular trauma, including shrapnel or debris to the eye, is easily identified and rapidly treated. Closed globe trauma may not be detected right away, and little is known about the time course of visual dysfunction following blast exposure. To better understand the mechanisms behind blast induced vision loss, we have developed a rodent model to characterize the time-dependent changes in visual acuity after blast exposure. To assess visual acuity in rodents, a custom vision behavioral device was built to measure the threshold for the natural optokinetic nystagmus reflex. The test animal is placed in the center of the device and a cylindrical sine wave grating is displayed on four surrounding computer monitors. The grating rotates around the animal, which causes the animal to reflexively track the grating motion with head movements. The level of grating contrast at which the direction of drift is correctly tracked by the animal represents the level of functional visual acuity. An increase in visual acuity indicates a decrease in vision functionality. For the present study, anesthetized Long-Evans rats were exposed to 230 kPa pressure waves using a compressed-air shock tube. Control animals were anesthetized and placed in the shock tube, but no pressure wave was activated. Visual acuity was assessed three times in each animal at three time points: before blast exposure, one day after exposure, and one week after exposure. Relative to baseline measurements, animals exposed to the blast pressure wave had a significant increase from visual acuity one day after the blast and then returned to pre-injury levels one week after the blast. No increase was found in control animals. This suggests that a low level blast may cause temporary visual dysfunction, but it is not sufficient to cause long-term injury. Future studies will investigate visual functionality at more severe levels of blast exposure and for later time periods after blast exposure.

TEMPORARY VISUAL DYSFUNCTION FOLLOWING LOW LEVEL BLAST EXPOSURE

PEDIATRIC HEAD TRAUMA
Injury Biomechanics Lab

Daniel F. Shedd and Brittany Coats, PhD
Mechanical Engineering, University of Utah, Salt Lake City, UT USA

Introduction

Blast exposure is a leading cause of eye injury for the US Army [1]. Typically, ocular injury occurs from explosive shrapnel and debris, but recently many soldiers have developed vision deficits 6-12 months following a blast exposure without any signs of injury [2]. Closed globe trauma may not be detected right away, and little is known about the time course of visual dysfunction following blast exposure. To better understand the mechanisms behind blast induced vision loss, we developed a rodent model to characterize the time-dependent changes in visual acuity after blast exposure using behavioral vision testing and optical coherence tomography (OCT).

Methods

Anesthetized Long-Evans rats (300-350g, n=12) were exposed to 230 kPa pressure waves using a compressed-air shock tube (Fig. 1). Control animals (n=12) were anesthetized and placed in the shock tube, but no pressure wave was activated. Animals were euthanized at 1 day, 1 week, 4 weeks, or 8 weeks post-blast.
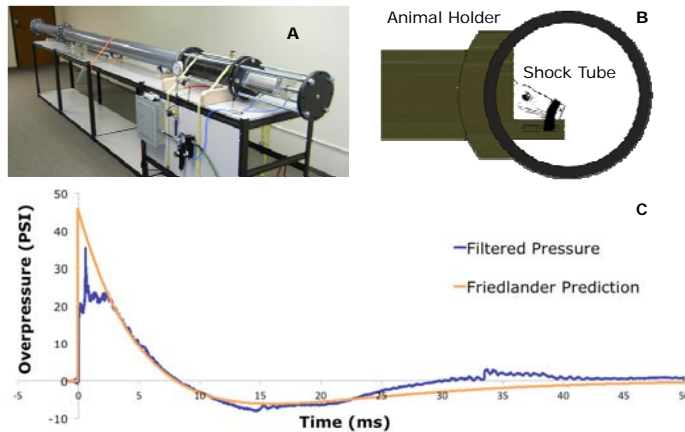

Fig. 1. (A) The 6″ experimental shock tube was triggered via rupturing BoPET membranes and instrumented with 1 MS/s pressure sensors (PCB 113B26) along the length of the driven section. **(B)** Animal placement within shock tube. **(C)** Representative filtered pressure profile used to apply blast insult. Comparison to ideal Friedlander waveform shown. R² = .92

A custom vision behavior device (Fig. 2) was built to measure the visual acuity threshold using the optokinetic nystagmus reflex. Test animals were placed in the center of the device and a cylindrical sine wave grating was displayed on four surrounding computer monitors. The grating rotated around the animal, which caused the animal to reflexively track the grating motion. The grating contrast at which the direction of drift was tracked by the animal represented the level of functional visual acuity (Fig. 3). Visual acuity was assessed three times in each animal at up to eight time points. A two-tailed matched-pair test with p=.05 was used to find significant vision changes. OCT imaging (Fig. 4) was performed using Bioptigen Envisu™ R2200 OCT scanner with an ultra-high resolution (UHR) light source and a rat retina lens. The scan settings were: 1000 A-scans per B-Scan, 100 B-scans over a field of view of 2.6 mm by 2.6 mm. Images were processed and analyzed using MATLAB [3] to find total retinal thickness and RPE thickness.

More information about the Utah Laboratory of Pediatric Injury Biomechanics is available at our lab website: pedtrauma.mech.utah.edu

Methods

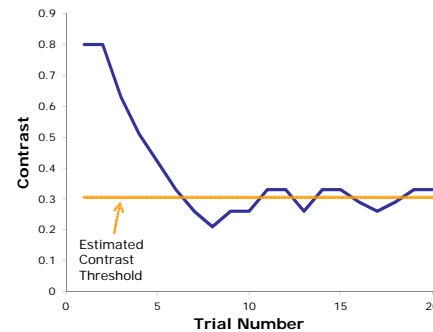**Figure 2.** Visual acuity behavior test device

Fig. 3. Representative plot identifying visual acuity in a rat following blast exposure.
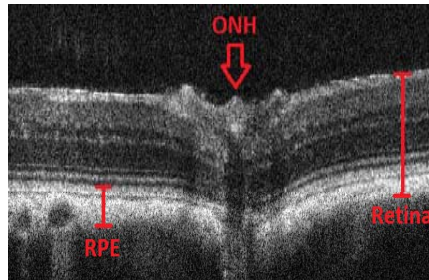

Fig. 4. Representative B-scan centered at optic nerve head (ONH). Total retinal thickness and RPE thickness were extracted across retina width and averaged. For the purposes of analysis, RPE included the photoreceptor inner/outer segments.

References

[1] DeFraites, R., *et al.*, Medical Surveillance Monthly Report, May 2011: 2-6. 2011.
[2] Cockerham, G., *et al.* Eye and visual function in traumatic brain injury. *Journal of Rehabilitation Research and Development* 46, 811-818. 2000.
[3] MATLAB and Image Processing Toolbox Release 2012b, The MathWorks, Inc., Natick, MA.

Results
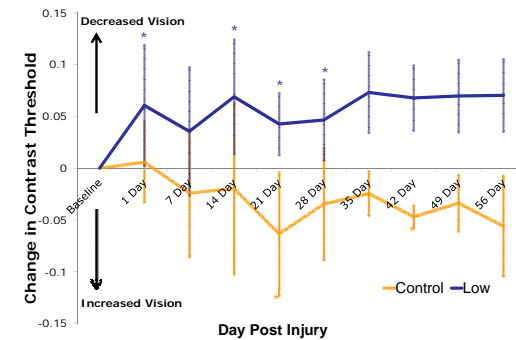
Fig. 5. Change in contrast threshold from baseline over time for control and low-level blast-exposed animals. * p<.05
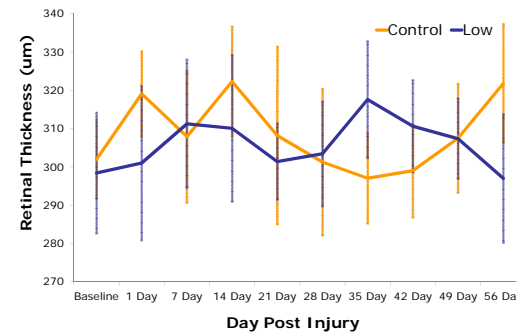
Fig. 6. Thickness of retinal layer over time, representing blast animals (n=3) and control animals (n=3). All data was gathered from eyes ipsilateral to blast insult. No significant trends were found.

Conclusions

- Blast-exposed animals exhibited decreased visual acuity at one day, two week, three week, and four week time points as measured by behavior testing.
- Control animals exhibited unchanged visual ability, with the exception of increased visual ability at three week and six week time points. This may be due to increased comfort with the behavior system.
- Retinal thickness did not significantly change in either group at any time point.

Acknowledgements

Contact Information

Daniel F. Shedd   Brittany Coats, PhD
Email: d.shedd@utah.edu Email: brittany.coats@utah.edu

BRITTANY COATS

University of Utah
50 S. Central Campus Drive, 2124 MEB
Salt Lake City, UT 84112

brittany.coats@utah.edu / pedtrauma.mech.utah.edu

EDUCATION

University of Pennsylvania   ***Philadelphia, PA***
Doctorate of Philosophy, Bioengineering   May 2007
Advisor: Susan S. Margulies, Ph.D.
Dissertation: Mechanics of Head Impact in Infants

University of Utah   ***Salt Lake City, UT***
Bachelors of Science and Engineering, Mechanical Engineering   May 2000

RESEARCH EXPERIENCE

Assistant Professor   ***University of Utah, 2010-Present***
Department of Mechanical Engineering   Salt Lake City, UT

Adjunct Assistant Professor   ***University of Utah, 2010-Present***
Department of Bioengineering   Salt Lake City, UT
Department of Pediatrics

Post-doctoral Research Associate   ***University of Pennsylvania, 2007-2010***
•Department of Neurosugery (2008-2010)   Philadelphia, PA
 Traumatic brain injury following cyclic inertial head rotation in neonatal piglets.
•Department of Bioengineering (2007-2010)
 Mechanics of ocular trauma in infants following inertial, non-impact head rotation.

Graduate Research Assistant   ***University of Pennsylvania, 2000-2007***
Department of Bioengineering   Philadelphia, PA
Mechanics and skull tolerance of infants following impact events.

Research Technician   ***Becton Dickinson, 1998-2000***
Research and development of infusion therapy systems.   Sandy, UT

Undergraduate Research Assistant   ***University of Utah, 1997-1998***
Department of Bioengineering   Salt Lake City, UT
Cardiovascular monitoring during patient flight transport.

PENDING RESEARCH FUNDING

National Science Foundation, CMMI   ***BMMB, 2014-2017***
Multiscale evaluation and simulation of the pia-arachnoid complex in head trauma

Role: PI
National Science Foundation   ***NICHD, 2014-2017***
Dynamics and control of magnetic screws in soft tissue

AWARDED RESEARCH FUNDING

University of Utah

National Institutes of Health   ***NICHD, 2013-2017***
Repair of iatrogenic fetal membrane defects with an adhesive tissue scaffold

Early Career Development Award - Renewal   ***PCMCF, 2013-2014***
Pediatric TBI from repetitive head rotation

 Role: PI

Knights Templar Eye Foundation – Competitive Renewal   ***KTEF, 2013-2014***
Biomechanical properties of the pediatric eye

 Role: PI

Department of Defense Vision Research Program   ***USAMRRA, 2012-2016***
Temporal progression of visual injury from blast exposure

 Role: PI

University of Pennsylvania Vision Research Seed Grant   ***UPENN, 2012-2013***
Decompression retinopathy and pediatric head trauma

Knights Templar Eye Foundation   ***KTEF, 2012-2013***
Biomechanical properties of the pediatric eye

 Role: PI

Early Career Development Award   ***PCMCF, 2012-2013***
Pediatric TBI from repetitive head rotation

 Role: PI

University of Utah Research Foundation Seed Award   ***URF, 2012-2013***
Quantification of collagen dissolution in the immature eye from plasmin protealase

 Role: PI

National Center for Injury Prevention & Control (R01-CE001445)   *CDC, 2008-2012*
Development and validation of a diagnostic tool for infant head injuries from falls

   Role: Multiple PI

University of Pennsylvania

National Center for Injury Prevention & Control (R01-CE001445)   *CDC, 2008-2012*
Development and validation of a diagnostic tool for infant head injuries from falls

   Role: Multiple PI

National Institute of Neurological Disorders (Kirschstein-NRSA Trainee)   *NIH, 2008-2010*
Development of a novel model for repeated cyclic rotational brain injuries.

National Center for Injury Prevention & Control (Research Dissertation Grant)   *CDC, 2004-2006*
Mechanics of head impact in infants

   Role: PI

SELECTED HONORS/DISTINCTIONS

2013	Teacher of the Year Award, Mechanical Engineering
2012	University of Utah nominee for the Packard Fellowship in Science and Engineering
2008	Recipient of David and Lindsay Morgenthaler Endowed Fellowship
2008	University Nominee for the Burroughs Wellcome Career Award at the Scientific Interface
2007	Solomon R Pollack Award for Excellence in Graduate Bioengineering Research
2001-2003	Stephenson Fellowship Award
2000-2004	Graduate Association of Bioengineers, President (2001-2003)
1999-2000	Clyde Christianson Scholarship
1999	Phi Beta Kappa, National Honor Society
1996	Tau Beta Pi, National Engineering Honor Society, Secretary (1997-1998)
1995-1999	Honors Scholarship

TEACHING EXPERIENCE

Assistant Professor   *University of Utah, 2010-Present*
Department of Mechanical Engineering   Salt Lake City, UT
ME EN 1300:   Statics and Introduction to Strengths of Materials (Spring 2011, 2012, 2013, 2014)
ME EN 5510/6510: Introduction to Finite Element Modeling (Fall 2011, 2012, 2014)
ME EN 3300:   Strength of Materials (Spring 2015)

Lecturer   *University of Pennsylvania, 2006-2008*
Department of Bioengineering   Philadelphia, PA
BE 100:   Introduction to Bioengineering (Fall 2006, 2007)
BE 200:   Biomechanics and Biomaterials (Fall 2006, 2007)
BE 210:   Sophomore Undergraduate Bioengineering Lab (Spring 2007, 2008)

BE 310:   Junior Undergraduate Bioengineering Lab (Spring 2007, 2008)
Graduate Instructor   ***University of Pennsylvania, 2005-2006***
Department of Bioengineering   Philadelphia, PA
BE 100:   Introduction to Bioengineering (Fall 2005)
BE 210:   Sophomore Undergraduate Bioengineering Lab (Spring 2006)
BE 310:   Junior Undergraduate Bioengineering Lab (Spring 2006)

Teaching Assistant   ***University of Pennsylvania, 2001-2004***
Department of Bioengineering   Philadelphia, PA
BE 100:   Introduction to Bioengineering (Fall 2004)
BE 200:   Biomechanics and Biomaterials (Fall 2003)
BE 350:   Transport Processes in Living Systems (Spring 2003)
BE 510:   Biomechanics and Biotransport (Spring 2001)
BE 567:   Modeling Biological Systems (Fall 2002)

SERVICE

Department of Mechanical Engineering
Distinguished Seminar Committee
- Chair (2012, 2013,2014)
- Member (2010, 2011)
Solid Mechanics Group
- Chair (2014)
Executive Committee
- Member (2014)
Undergraduate Curriculum Committee
- Member (Spring 2014, Spring 2013)
Graduate Committee
- Member (2014)
Faculty Search Committees
- Chair (Computational Mechanics, 2013)
- Member (Computational Mechanics, 2011, 2012)
- Member (Experimental Mechanics, 2014)

Department of Pediatrics
Fellows Program
- Fellowship Advisor (2013-Present)

College of Engineering
Tau Beta Pi
- Advisor (2014-Present)
FE Exam Student Review
- Statics reviewer (Spring 2013)

PROFESSIONAL SOCIETY MEMBERSHIPS

- American Society for Engineering Education (ASEE)
- Association for Research in Vision and Ophthalmology (ARVO)

•Association of Women in Science (AWIS)
•American Society of Mechanical Engineers (ASME)
•Biomedical Engineering Society (BMES)
•National Neurotrauma Society (NNS)
•Tau Beta Pi (TBP)

AD HOC REVIEWER

•Annals of Biomedical Engineering
•Archives of Pediatric and Adolescent Medicine
•ASME Journal of Biomechanical Engineering
•BioMedical Engineering OnLine
•Computer Methods in Biomechanics and Biomedical Engineering
•Computational Modeling in Biomechanics
•IASTED Biomech 2011
•International Journal of Numerical Methods
•Investigative Ophthalmology & Visual Science
•JAAPOS
•Journal of Biomechanics
•Journal of Clinical Anatomy
•Pediatrics

GRANT REVIEWER

Centers for Disease Control
National Center for Injury Prevention and Control (NCIPC)
Special Emphasis Panel (Fall 2009)

National Science Foundation
Nano and Biomechanics Program (Spring 2011)
Biomechanics and Mechanobiology (Spring 2012)

South Plains Foundation
Lubbock, TX (Summer 2011)

PUBLICATIONS

Book Chapters

1. Margulies SS and **Coats B**. Biomechanics of pediatric TBI. In V. Anderson & K. Yeates (Eds), *Pediatric Traumatic Brain Injury: New Frontiers in Clinical and Translational Research.* New York: Cambridge University Press. (2010)

2. Margulies SS and **Coats B.** Biomechanics of head trauma in infants and young children. In C. Jenny (Ed) *Child Abuse and Neglect: Diagnosis, Treatment and Evidence*. Philadelphia: Saunders/Elsevier. (2010)

3. Coats B and Margulies SS. Material properties of the pediatric head. In J. Crandall, D. Meaney, & B. Myers (Eds), *Pediatric Injury Biomechanics: Arcihve and Textbook*. New York: Springer. (2012)

4. Grant E, **Coats B**, Hedlund G. Neuroimaging. In P. Kleinman (Ed.) *Diagnostic Imaging of Child Abuse.* 3rd Edition. Elsevier Science Health, St. Louis Missouri (2014)

5. Frasier L, **Coats B**, Kleinman P. Abusive Head Trauma. In P. Kleinman (Ed.) *Diagnostic Imaging of Child Abuse.* 3rd Edition. Elsevier Science Health, St. Louis Missouri (2014)

Peer-Reviewed Journal Publications
*Students of Coats B, *Mentorees* of Coats B

1. Prange MT, **Coats B**, Duhaime AC, and Margulies SS. Anthropomorphic simulations of falls shakes, and inflicted impacts for infants. J Neurosurg 2003, 99: 143-150

2. **Coats B** and Margulies SS. Characterization of pediatric porcine skull properties during impact, Proce Int Conf of Biomech of Impacts. 2003: pp. 57-66.

3. **Coats B** and Margulies SS**.** Material properties of porcine parietal cortex. J Biomech. 2006, 39(13):2521-5.

4. **Coats B** and Margulies SS. Material properties of human infant skull and suture at high rates. J. Neurotrauma. 2006 Aug, 23(8):1449-59.

5. **Coats B, Ji S** and Margulies SS. Parametric study of head impact in the infant. Stapp Car Crash Journal. 2007 Oct, 51:1-15.

6. **Coats B** and Margulies SS. Potential for head injury in infants from low height falls.   J. Neurosurgery: Pediatrics. 2008 Nov, 2(11):321-30. (**Selected for journal cover and editorial feature)**

7. Margulies SS, **Coats B**, Christian C, Forbes B, Duhaime AC. What can we learn from computational model studies of the eye? JAAPOS. 2009 Aug; 13(4):332.

8. Ibrahim NG, Natesh R, Szczesny SE, Ryall K, Eucker SA, **Coats B**, Margulies SS. *In Situ* deformations in the immature brain during rapid rotations. J Biomechanical Eng. 2010 Apr; 132(4)

9. **Coats B**, Binenbaum G, Peiffer RL, Forbes BJ, Margulies SS. Ocular hemorrhages in neonatal porcine eyes from single, rapid rotational events. Investigative Ophthalmology & Visual Science (IOVS). 2010 Sept; 51(9)

10. **Coats B**, Eucker S, Sullivan S, Margulies SS. Finite element model predictions of intracranial hemorrhage from non-impact rapid head rotations in the piglet. International Journal of Developmental Neuroscience. Special Issue. 2012. Jan. 5

11. Moran P and **Coats B**. Biological sample preparation for SEM imaging of immature porcine retina. Microscopy Today. Jan 2012; 10-12.

12. *Tsai A*, **Coats B**, Kleinman PK. Stress profile of infant rib in the setting of child abuse: a finite element parametric study. Journal of Biomechanics. 2012 Jul; 45(11):1861-8.

13. Brooks BD, Sinclair KD, Davidoof SN, Lawson S, Williams AG, **Coats B**, Grainger DW, and Brooks AE. Molded polymer-coated composite bone void filler improves tobramycin controlled release kinetics. Journal of Biomedical Materials Research Part B: Applied Biomaterials. Epub ahead of print: Dec 2013.

14. Colter J, Williams AG, Moran P and **Coats B**. Dynamic moduli of immature ovine vitreous using spectrum interconversion. Journal of Mechanical Behavior of Biomedical Materials. Special Issue: Biomechanics of Impact. *In Press*.

15. Payne A, de Bever J, *Farrer A*, **Coats B**, Parker DL, Christensen DA. A simulation technique for three-dimensional MR-guided acoustic radiation force imaging. Medical Physics. Revision submitted August 2014.

16. Sullivan S, Eucker SA, Gabrieli D, Bradfield C, **Coats B**, Maltese MR, Lee J, Smith C, Margulies SS. White matter tract oriented deformation predicts traumatic axonal brain injury and reveals rotational direction-specific vulnerabilities. Biomechanics and Modeling in Mechanobiology. Revision submitted September 2014.

17. *Huizhong L*, Gehrke C, Sant H, **Coats B**, Agarwal J, Gale BK. A new vascular coupler design for ent-to-end anastomosis: fabrication and proof-of-concept evaluation. Journal of Medical Devices. Submitted July 2014.

18. Sullivan S, **Coats B**, Margulies SS. Head kinematics following low height falls. Annals of Biomedical Engineering. Submitted May 2014.

19. Saffioti JM and **Coats B**. Age, region and strain dependent material properties of the ovine sclera. J. Biomechanics. Submitted July 2014.

20. Scott GG and Coats B. Microstructural characterization of the pia-arachnoid complex using optical coherence tomography. Journal of Neurotrauma. Submitted July 2014

Peer-Reviewed Journal Publications in Preparation

1. Saffioti JM and **Coats B**. Characterizing the effect of post-mortem time and storage condition on the mechanical properties of immature and adult ovine sclera. J. Biomechanics (expected October 2014 submission)

2. Scott GG and Coats B. Multiscale modeling of the pia-arachnoid complex. Computational Modeling in Biomechanics (expected October 2014 submission).

3. Evans SM, Coats B and Binenbaum G. Rapid decompression of the eye as a mechanism for retinal hemorrhage. Journal of Ophthalmology (expected November 2014 submission)

3. Evans SM and Coats B. Retinal vein occlusion as a mechanism for retinal hemorrhage. Experimental Eye (expected January 2015 submission)

5. Jones J, Duhaime AC, Smith C, Margulies SS and **Coats B**. Pediatric head injury from repetitive head rotation. (expected December 2014 submission)

4. Nelson N, Williams AG, **Coats B**, and Abbott J. Influence of media material properties on screw trajectory. (expected March 2015 submission)

3. Evans SM and Coats B. The physiological effect of crying on repetitive head trauma. Journal of Pediatrics (expected November 2015 submission)

Conference Posters

1. Prange MT, **Coats B**, Raghupathi R, Duhaime AC, Margulies SS. Rotational Loads During Inflicted and Accidental Infant Head Injury, National Neurotrauma Symposium, San Diego CA. November 2001.

2. **Coats B** and Margulies SS**.** Material properties of porcine parietal cortex. World Cong. on Biomech. Aug. 2002.

3. **Coats B** and Margulies SS. Mechanical properties of human pediatric skull at high impact rates. ASME Summer Bioeng Conference, Vail, CO, June 2005. **Student Paper Competition Finalist**

4. **Coats B** and Margulies SS. High rate material properties of infant cranial bone and suture. National Neurotrauma Symposium, Washington DC, November 2005.

5. Ibrahim NG, **Coats B**, and Margulies SS. Response of the toddler and infant head during shaking. National Neurotrauma Symposium, Washington DC, November 2005.

6. **Coats B**, Ji S, Margulies SS. Using computational models to predict skull fracture in the infant. Pediatric Abusive Head Trauma, Hershey, PA, July 2007

7. Ibrahim NG, **Coats B**, and Margulies SS. Kinematics of the infant and toddler head during low height falls. National Neurotrauma Symposium, Florida, July 2008

8. **Coats B**, Binenbaum G, Pieffer RL, Forbes BJ, Margulies SS. Ocular hemorrhages from rapid, rotational accelerations. Association for Research in Vision and Ophthalmology, Ft. Lauderdale, FL, May 2009

9. **Coats B**, Kras J, Eucker, S, Margulies SS. Severity of extra-axial hemorrhage from non-impact inertial head rotation in the immature pig varies with direction. Neurotrauma, Santa Barbara, CA, September 2009

10. **Coats B**, Sullivan S, and Margulies SS. Development of a finite element model for predicting subdural hemorrhage from rapid non-impact head rotations. Neurotrauma, Las Vegas, NV, June 2010.

11. **Coats B**, Binenbaum G, Peiffer RL, Sullivan S, Ralston J, Smith C, Duhaime AC, Margulies SS. Ocular and Neuropathology from repetitive, low-velocity head rotations in immature pigs. Neurotrauma, Fort Lauderdale, FL, July 2011

12. Moran P. and **Coats B**. Development of rheometry tools for preventing wall slip in immature porcine vitreous. 7th Annual Utah Biomedical Engineering Conference. Salt Lake City, UT, September 2011.

13. Williams A, Nelson N, Abbott J and **Coats B**. Finite element analysis of a magnetically driven screw through soft tissue. 7th Annual Utah Biomedical Engineering Conference. Salt Lake City, UT, September 2011

14. Hashmi SK, Sullivan S, Eucker SA, **Coats B**, Lee J, Margulies SS. FEM-predicted regional tissue strains aligned with the white matter tracts predict axonal injury. Northeast 38th Annual Bioengineering Conference (NEBEC). Philadelphia, PA. March 2012

15. Moran P. and **Coats B**. A rheological technique for extracting dynamic moduli from creep testing of pediatric porcine vitreous. Proceedings of the ASME 2012 Summer Bioengineering Conference Fajardo, Puerto Rico, June 2012. (**Master's Student Paper Finalist)**

16. Saffiotti JM and **Coats B**. Development of a finite element model for intraocular pressure predictions in children. Proceedings of the 11th International Symposium of Computer Methods in Biomechanics and Biomedical Engineering. Salt Lake City, UT. April 2013.

17. Shedd DF and **Coats B**. Verification of a shock tube finite element model for blast ocular injury simulations. Proceedings of the 11th International Symposium of Computer Methods in Biomechanics and Biomedical Engineering. Salt Lake City, UT. April 2013.

18. Saffioti JM and **Coats B**. Age dependent and anisotropic material propertis of immature porcine sclera. Proceedings of the ASME 2013 Summer Bioengineering Conference. Sun River, Oregon. June 2013.

19. Farrer AI, de Bever J, **Coats B**, Christensen DA, Payne A. Fabrication and evaluation of tissue-mimicking gelatin phantoms for use with MR-ARFI and MRgFUS. 14th International Symposium on Therapeutic Ultrasound. Las Vegas, NV. April 2014.

20. <u>Shedd DF</u> and **Coats B**. Temporary visual dysfunction following low-level blast exposure. 7th World Congress of Bomechanics. Boston, MA. July 2014.

22. <u>Saffioti JM</u> and **Coats B**. The effect of post mortem time on the material properties of immature and adult ovine sclera. 7th World Congress of Biomechanics. Boston, MA July 2014.

23. <u>Colter JC</u>, <u>Williams A</u>, <u>Moran P</u>, **Coats B**. Dynamic moduli of immature ovine vitreous using advanced rheology techniques. 7th World Congress of Biomechanics. Boston, MA July 2014. **BS Student Finalist**

23. <u>Evans SM</u>, Smith C and **Coats B**. The effect of physiological changes due to crying on repeated pediatric head trauma. 7th World Congress of Biomechanics. Boston, MA July 2014.

24. *Farrer A*, Odeen H, de Bever J ,**Coats B**, Christensen D, Payne A. Development and characterization of tissue-mimicking gelatin phantoms for use with MRgFUS. Biomedical Engineering Society. San Antonio, TX Oct 2014

25. Binenbaum G, <u>Evans S</u>, Lee V, **Coats B**. Evaluation of optic nerve compression as a potential cause of retinal hemorrhage in infants. AAPOS 41st Annual Meeting. New Orleans, LA March 2015

Conference Podium Presentations

1. **Coats B** and Margulies SS. Characterization of pediatric porcine skull properties during impact, Proce Int Conf of Biomech of Impacts. 2003: pp. 57-66.

2. **Coats B,** Ji S and Margulies SS. Parametric study of head impact in the infant. Stapp Car Crash Journal. 2007 Oct, 51:1-15.

3. **Coats B**, Ji S, Margulies SS. Using computational models to predict skull fracture in the infant. Pediatric Abusive Head Trauma, Hershey, PA, July 2007

4. **Coats B**, Binenbaum G, Pieffer RL, Forbes BJ, Margulies SS. Ocular hemorrhages from rapid, rotational accelerations. Association for Research in Vision and Ophthalmology, Ft. Lauderdale, FL, May 2009

5. **Coats B**, Binenbaum G, Pieffer RL, Forbes BJ, Margulies SS. Ocular hemorrhage in single, non-impact head rotations: a porcine model. Pediatric Abusive Head Trauma Conference, Jackson Hole, WY, June 2009

6. Herman BE, **Coats B**, Corwin DL. Detailed confessions and reenactments utilizing biomechanical dolls: What do they tell us? Pediatric Abusive Head Trauma Conference, San Francisco, CA. July 2011.

7. Coats B, Corwin D, Herman B. Video recorded reenactment of inflicted head and other injuries to a three-week old infant: biomechanical, clinical and psychosocial observations and perspectives. International Conference on Child & Family Maltreatment, San Diego, CA. January 2012

8. **Coats B** and Binenbaum G. Progress toward understanding mechanisms of retinal hemorrhage. 12th International Conference on SBS/AHT. Boston, MA September 2012.

9. <u>Scott GG</u> and **Coats B**. Microscale finite element model of the pia arachnoid complex in shear: a parametric evaluation. Proceedings of the 11th International Symposium of Computer Methods in Biomechanics and Biomedical Engineering. Salt Lake City, UT. April 2013.

10. <u>Evans SM</u>, Smith C and **Coats B**. The effect of physiological changes due to crying on repeated pediatric head trauma. 17th U.S. National Congress on Theoretical and Applied Mechanics. East Lansing, MI. June 2014

11. <u>Scott GG</u> and **Coats B**. Microscale finite element modeling and optical coherence tomography imaging of the pia arachnoid complex. 17th U.S. National Congress on Theoretical and Applied Mechanics. East Lansing, MI. June 2014.

INVITED TALKS
*expenses paid by host

Biomechanics of retinal injuries. Abusive Head Trauma Conference. Park City, UT. July 2015*

The effect of the volume fraction and damage of arachnoid trabeculae on traumatic brain injury. Neuroscience Grand Rounds. Department of Neuroscience. University of Winnipeg. Canada. December 2014*

The mechanics of arachnoid trabeculae and their influence on traumatic brain injury: a multiscale investigation. Department of Biomedical Engineering. University of Winnipeg. Canada. December 2014*

Developing a better method of understanding SBS through biomechanical and pathological research. 14th International Conference on SBS/AHT. Denver, CO. September 2014*

Understanding mechanisms of retinal hemorrhage through experimentation, mechanical testing, and imaging. 14th International Conference on SBS/AHT. Denver, CO. September 2014*

Microscale finite element modeling and optical coherence tomography imaging of the pia arachnoid complex. 7th World Congress of Biomechanics. Boston, MA. June 2014.

Modern research on retinal hemorrhages in abusive head trauma. Abusive Head Trauma Conference. Burlington, VT. June 2013* (declined due to scheduling conflict)

Finite element modeling in research and education. ANSYS Medical Device Forum. Salt Lake City, UT. October 2012*

Progress toward understanding mechanisms of retinal hemorrhage. 12th International Conference on SBS/AHT. Boston, MA. September 2012*

Predicting injury in pediatric head and eye trauma: Combining simulations and databases. Department of Biomedical Informatics, University of Utah. Salt Lake City, UT. September 2012

Abusive head trauma: a case, a confession, and the biomechanics involved. Trauma Research and Education Meeting. Trauma Department at Primary Children's Medical Center. Salt Lake City, UT. December 2010

Using biomechanics to understand SBS/AHT. 11th International Conference on SBS/AHT. Atlanta, GA. September 2010.*

What biomechanics has taught us about pediatric TBI. Ground Rounds Seminar. Department of Pediatrics at Primary Children's Hospital. Salt Lake City, UT. February 2010.*

Using biomechanics to elucidate mechanisms of retinal hemorrhages in children. Ground Rounds Seminar. Department of Ophthalmology at Moran Eye Center. Salt Lake City, UT. October 2009.*

Biomechanics of pediatric head and eye injury in accidental and inflicted trauma. Department of Mechanical Engineering at University of Utah. Salt Lake City, UT. July 2009.

Ocular hemorrhages in single, non-impact had rotations: a porcine model. Penn State College of Medicine. Jackson Hole, WY. June 2009.

Biomechanics of brain, skull, and eye injury in abusive head trauma. Cole Eye Institute and Cleveland Clinic Lerner Research Institute. Cleveland, OH. December 2008.*

Mechanics of head impact in infants. CNS Seminar. Department of Neurosurgery at the Hospital of the University of Pennsylvania. Philadelphia, PA. September 2007.

Biomechanics in pediatric head injury. Summer Academy in Applied Science and Technology. Philadelphia, PA. August 2007

Using computational models to predict skull fracture in the infant. Penn State College of Medicine. Hershey, PA. July 2007.

Head injury biomechanics in infants. Department of Mechanical Engineering at Virginia Tech. Blacksburg, VA. March 2007.*

Predictions of skull fracture in infants. Center for Brain Injury Research. Philadelphia, PA. November 2006.*

Mechanics of head impact in infants. CDC New Investigator Workshop. Atlanta, GA. May 2005.*

Characterization of pediatric porcine skull properties during impact. International Research Council on the Biomechanics of Injury. Lisbon, Portugal. September 2003.